THE EFFECT OF PROLONGED STAY UNDER CONDITIONS OF LOWERED BAROMETRIC PRESSURE ON TOLERANCE OF G-LOADS

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In experiments on white mice, rats and guinea pigs we studied the effectiveness of the influence of adaptation to hypoxia on the tolerance of transversely directed G-loads. It was established that both an interrupted 14-day pressure-chamber adaptation to hypoxia with evacuation from 528.5 to 307 mm Hg and a 30-day acclimatization under high-altitude conditions (Mt. Elbrus) at an altitude of 2000 - 3800 m produces an increase in the survivability under the influence of G-loads of adapted mice on an average of 25%, in rats of 19%, in guinea pigs of 30%. Here it was noted that the adaptation effect is retained approximately for a period of 3 weeks. Both types of conditioning are accompanied by an increase in the amount of hemoglobin and number of erythrocytes in the peripheral blood of the animals.

A significant amount of research has been devoted to seeking /97 means and methods of increasing tolerance to the effect of G-loads.

A rather high effectiveness has already been established for anti-G-load suits (which have already found use in aviation [1, 8, 13, 26]), for immersion environments [22, 25, 28], for pharmacological compounds [5, 16, 20], for physical conditioning [11, 17] and for several others.

It is known that with a prolonged effect of transversely directed G-loads ane of the leading links in pathogenesis of the approaching disorders is the oxygen starvation of the vital organs and tissues.

At the present time it has been strictly established that conditioning to oxygen deficiency increases the tolerance of the organism to the effect of many environmental factors [2, 4, 12, 23]. Therefore it is feasible to continue the research begun by N.N. Sirotinin [15] on studying the possibility of using adaptation of the organism to hypoxia for increasing tolerance to G-loads.

The problem of this research was to determine the degree of effectiveness of adaptation to hypoxia for the tolerance of animals to transversely directed G-loads and to establish the times of readaptation.

The research was conducted on 730 white mice, 119 white rats and 28 guinea pigs. The experiments were carried out with adaptation of the animals under pressure-chamber and high-altitude con-

ditions. The length of the adaptation under pressure-chamber conditions was 14 days and consisted of daily six-hour sessions at altitudes of: 1st day, 3000 m; 2nd-3rd days, 4000 m; 4th day, 4500 m; 5th-7th days, 5000 m; 8th day, 5500 m; 9th day, 6000 m; 10th-11th days, 6500 m; 12th-14th days, 7000 m. During the adaptation the humidity in the pressure chamber was kept at a level of 50-70% and the temperature at 25-27° C.

Acclimatization under high-altitude conditions was carried out in the region of Mt. Elbrus at an altitude of 2000-3800 m above sea level.

G-loads of 45 units for the white and mice and 25-30 units for the white rats and the guinea pigs were reproduced on a centrifuge with a radius of 4.7 m for the 1st-6th days and 9th-18th days following completion of the adaptation.

Evaluation of the tolerance to G-loads was conducted on the /98
basis of comparing survival in the experimental and the control groups; in the experiments on rats and guinea pigs, furthermore, the character and degree to which the disruptions occured in heart function were analyzed from data of the electrocardiogram and change in respiration.

For the purpose of studying the dynamics of the acclimatization process in the experimental animals we periodically determined the amount of hemoglobin, the erythrocytes and reticulocytes in the peripheral blood, the oxygen requirement and the body weith. Here we established the following: the increase in the number of erythrocytes in the white mice subjected to the pressure chamber increased maximally to 3,450,000; in the white rats to 1,260,000 and in the guinea pigs to 800,000. The hemoglobin increased by 5, 1.4 and 0.6 g%, respectively. The increase in the erythrocytes in the white mice, subjected to an altitude of 3800 m, equaled 125,000; in the rats it was 780,000 and in the quinea pigs, 350,000. The increase in hemoglobin did not exceed 2.6 g%. These results agree with the literature data [9, 14, 18-21, 27]. With equivalent conditions of volume and feeding the weight of the animals varied differently. As a rule, a large increase in weight was observed in the control animals. The experimental mice, rats and guinea pigs, if they had an increase in weight, had a gain that was less than that of the control animals.

The gaseous metabolism of the animals adapted both to pressure chamber conditions and those of high altitude, had a slight tendency to decrease, however, the differences in statistical interpretation were found to be insignificant. Analogous results were obtained also by other authors. Thus, according to the data of Kreps et al the gaseous metabolism of the "hypoxic" rats at rest (in an environment of atmospheric air) did not differ from that of the control animals [10].

In analyzing the cardiac activity almost in all experiments during the time of the G-load effect, bradycardia set in significantly earlier and deeper in the control rats and guinea pigs, as shown by the collapse of the compensatory mechanisms (Fig. 1). With the beginning of rotation, an increase in respiration was observed. However with a G-load of 15 - 20 units, difficulty developed in the respirational movements and on the curves of registering the perimeter of the chest a flat line was often recorded (Fig. 2). In the period of recovery in the majority of cases an expressed compensatory shortness of breath was observed. Here no pronounced differences were noted in the change in breathing between the control and the experimental animals.

The tolerance of the animals to the effect of G-loads was most distinctly expressed during the first rotation in the centrifuge conducted on the 1st - 6th days following adaptation (Table 1).

From the data cited, it is clear that in all experimental groups, without exception, the survival was greater than in the control animals. Thus the survival of the adapted white mice exceeded that among the control animals by 28.1% (t = 5.3); and in the rats, by 19.5% (t = 1.96). /99

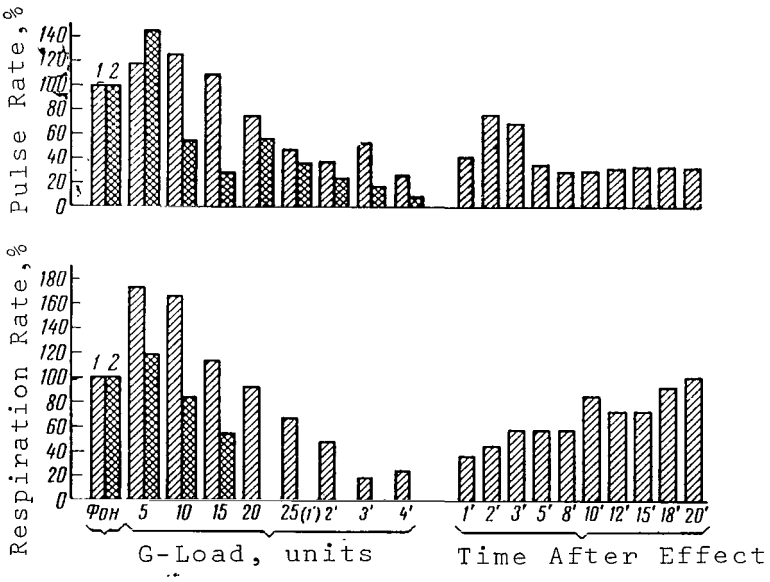

Fig. 1. Dynamics of the Pulse and Breathing Rate in Adapted (1) and Control (2) Guinea Pigs Acted on by G-Loads.

A similar picture was observed during rotation of the animals acclimatized under high-altitude conditions (Table 2). In the mice the difference in survival during the times of the test reached 23.5% (t = 1.91) and in the guinea pigs, 30% (t = 1.4).

With the action of the G-loads on the 9th - 18th days after completetion of the adaptation the difference in survival was already less contrasting, i.e., a gradually approaching loss was observed in the increased tolerance of the animals adapted to hypoxia. On the 28th day the increased tolerance to G-loads, as we reported previously [7], was retained only in the animals who had undergone active acclimatization (hypoxia + physical conditioning). It is interesting that in animals who were adapted under pressure-chamber conditions more expressed changes were observed from the side of the characteristics of the red blood; they possessed somewhat higher tolerance to G-loads and lost them later than the mice and the rats acclimatized (without physical load) at high altitude.

A lower degree of acclimatization effect in the animals conditioned under high-altitude conditions is explained apparently by the fact that the maximal evacuation in the mountains was only 474 mm Hg (3800 m), whereas in the pressure chamber it was equal to 307 mm Hg (7000 m).

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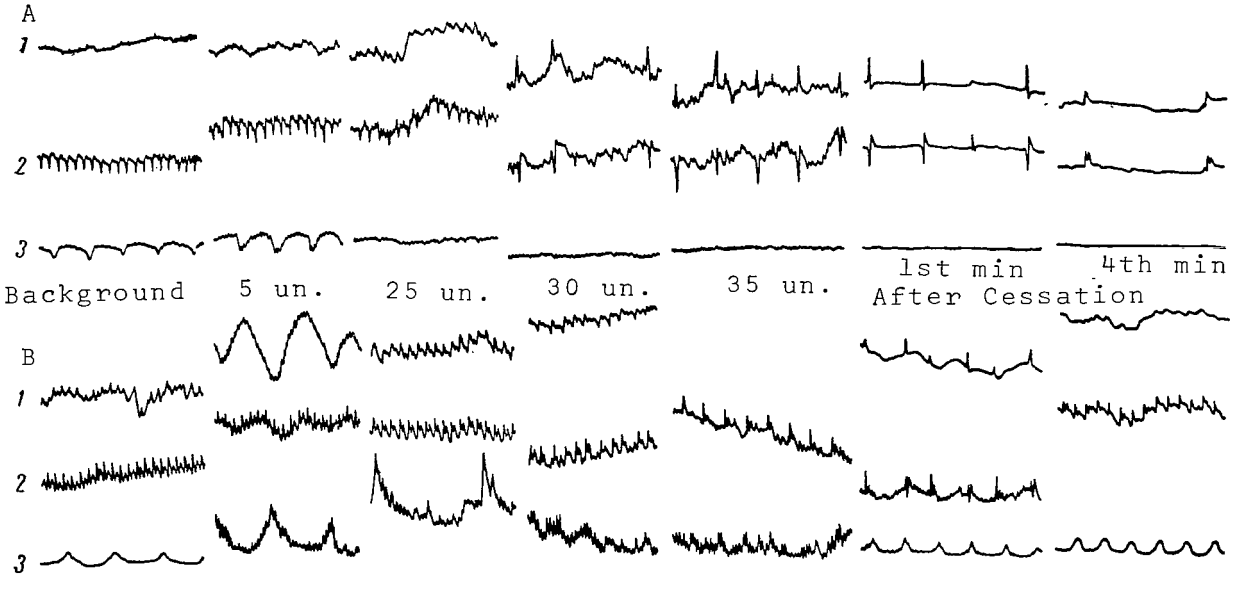

Fig. 2. Change in the EKG and Respiration in Control (A) and Adapted (B) White Rats Acted on by G-Loads. 1. EKG, Lead I; 2. EKG, Lead II; 3. Pneumogram.

TABLE 1. SURVIVAL OF CONTROL ANIMALS AND THOSE ADAPTED TO HYPOXIA UNDER PRESSURE-CHAMBER CONDITIONS ACTED ON BY G-LOADS. /101

Animals	Group	Number of Animals	Days of Rotation in Centrifuge	Result		Survival, %
				Died	Lived	
Mice	Control	141		85	56	39.7
	Adapted	140	1 - 6	45	95	67.8
	Control	113		69	54	47.7
	Adapted	151	9 - 18	64	87	57.6
Rats	Control	40		29	11	27.5
	Adapted	49	1 - 6	26	23	47
	Control	15		11	4	27
	Adapted	15	9 - 16	8	7	47

TABLE 2. SURVIVAL OF CONTROL ANIMALS AND THOSE ACCLIMATIZED TO HYPOXIA UNDER HIGH-ALTITUDE CONDITIONS ACTED ON BY G-LOADS.

Animals	Group	Number of Animals	Days of Rotation in Centrifuge	Result		Survival, %
				Died	Lived	
Mice	Control	48		29	19	39.9
	2100 m	47	4	25	22	46.8
	3800 m	30		11	19	63.4
	Control	20		14	6	30
	2100 m	20	15	13	7	35
	3800 m	20		15	5	25
Guinea Pigs	Control	10		6	4	40
	Acclimatized	10	5 - 14	3	7	70
	Control	4		4	0	0
	Acclimatized	4	28	4	0	0

Thus, in the experiments on the various types of animals, we believe it has been definitely proven that a favorable effect of adaptation to hypoxia is exerted on the tolerance of G-loads. These data are confirmed by subsequent research carried out in our laboratory on humans [6].

Analysis of the results of these investigations and comparison of them with clinical-physiological reactions to the effect of hypokinesis and weightlessness (decrease in the mass of the circulating blood, plasma loss, decrease in the number of erythrocytes and the hemoglobin, deterioration in the blood supply of a number

of organs and tissues, decrease in the muscular tonus and the overall tolerance to forces of gravity) permit us to assume that the use of hypoxia may be an effective method of maintaining high tolerance of the organism of astronauts under conditions of prolonged flight. /102

Proceeding from the similar character of the reactions of the organism to hypodynamia and hypoxia, L.E. Lemb arrives at analogous recommendations for pilots of space craft [24].

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